Appendix I

Performance of BPA Analog Communication Channels

This appendix relates to Chapter 6, §6.8

HVDC modulation. BPA's Pacific HVDC Intertie modulation control implemented in 1976 used a remote power (later current) signal from the parallel Pacific AC Intertie [6-32,6-33,6-2]. The all-analog control used wide bandwidth (up to 20 Hz) transducers and microwave communications. The transmitted signal was the derivative of the measured power or current, which is an approximation of the frequency difference between the Pacific Northwest and Pacific Southwest areas.

The necessary protective filters and other filtering/compensation were included. This early wide-area control (remote input signal, real and reactive power outputs at dc terminals 1360 km apart) was successful. The modulation was removed from service in 1989 at the time of the expansion to four terminals by the addition of converter groups at both ends. Reasons for removal included declining need, cost and complexity of an upgraded digital control system for the four terminal link, and unavailability of secondary response signals from the southern end.

Monitor facilities. BPA control center monitor facilities represent evolving compromises among information needs, costs, available technology, and work schedules. The convention of using a 20 sps recording undersamples BPA's 20 Hz transducers and communication channels—for which 60 sps would be far more appropriate—but it's more than ample for the transducers and channels with bandwidths below 2 Hz. Protective filters to eliminate out-of-band signal anomalies are desirable. These were not in place for the brake test of September 4, 1997 [2-31]. Therefore special precautions are needed to separate measurement artifacts from actual power system behavior.

Figure I-1 shows the time intervals for the analyses to follow. Figure I-2 shows the spectral range to the 30 Hz limit imposed by 60 sps recording. Without further information, the two strong peaks might very well be interpreted as shaft activity or network resonances.

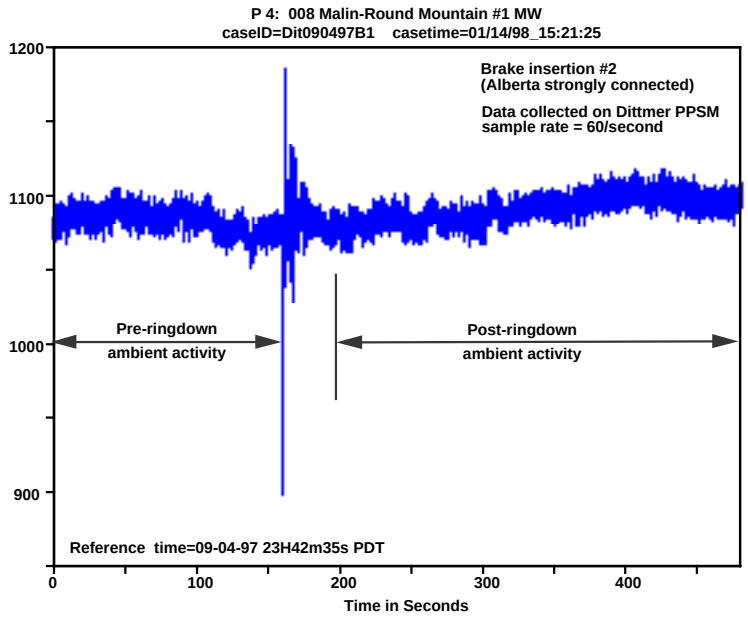

Fig. I-1. Record segments used in Fourier analysis of ambient activity, before and after brake insertion #2.

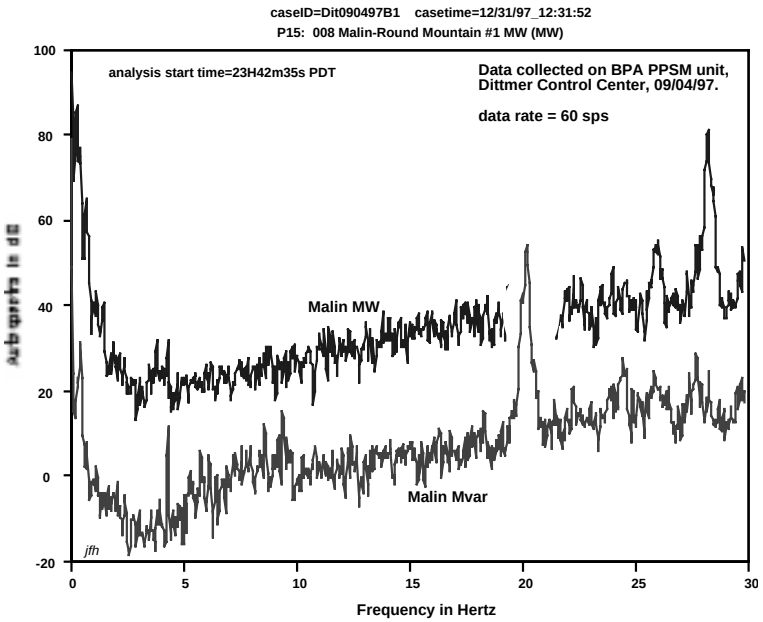

Fig. I-2. Anomalous activity peaks in real and reactive power on Malin–Round Mountain circuit #1, as viewed with 60 sps sampling.

Figures I-3 and I-4 show a more complex situation on the signal for real power on the MPC-Garrison 500-kV line. The first figure shows many odd peaks, with no obvious relationship among them. The second figure shows the corresponding spectrum for data collection at the standard 20 sps rate. Due to the lack of protective filtering, every peak located at or above 20 Hz in Figure I-3 has been “aliased” to a frequency below 10 Hz in

Figure I-4. Figure I-5, based upon the signal for the MPC–Garrison 230-kV line, illustrates the aliasing process for downsampling to 30 sps and 20 sps.

The observations to this point demonstrate that a 60 sps data rate may not be sufficient to establish the true frequencies, and thereby the likely natures, of the anomalous spectral peaks. Figures I-6 and I-7 are based upon earlier data that were collected at higher rates for precisely this reason. Periodicity and spacing of the peaks in Figure I-4 suggest that the peaks are displayed at their true frequencies and represent subcarrier activity. They reappear in Figures I-3 and I-4 at lower frequencies as a result of aliasing.

Figure I-7 shows very different characteristics for a signal associated with the Slatt TCSC. Spectral anomalies vary a lot from one signal to the next, and some signals are entirely free of them.

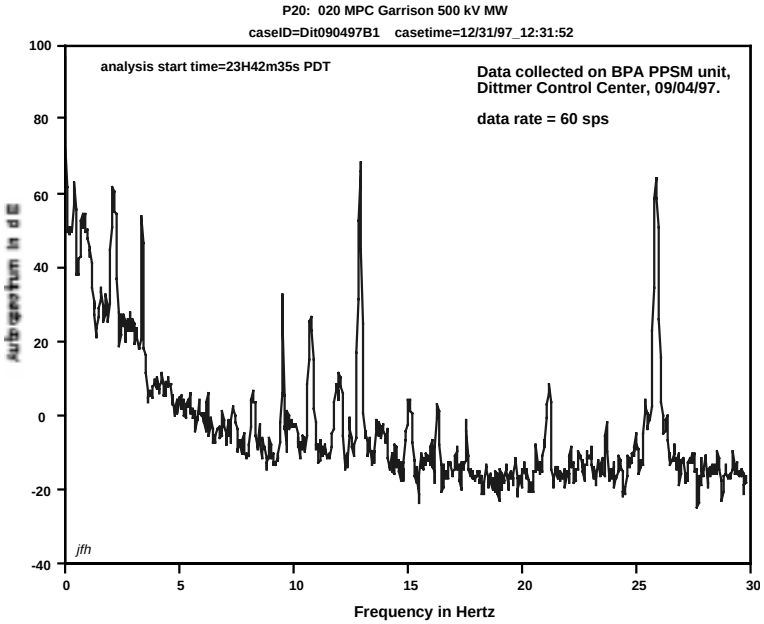

Fig. I-3. Anomalous activity peaks in real power on the MPC–Garrison 500-kV line, as viewed with 60 sps sampling.

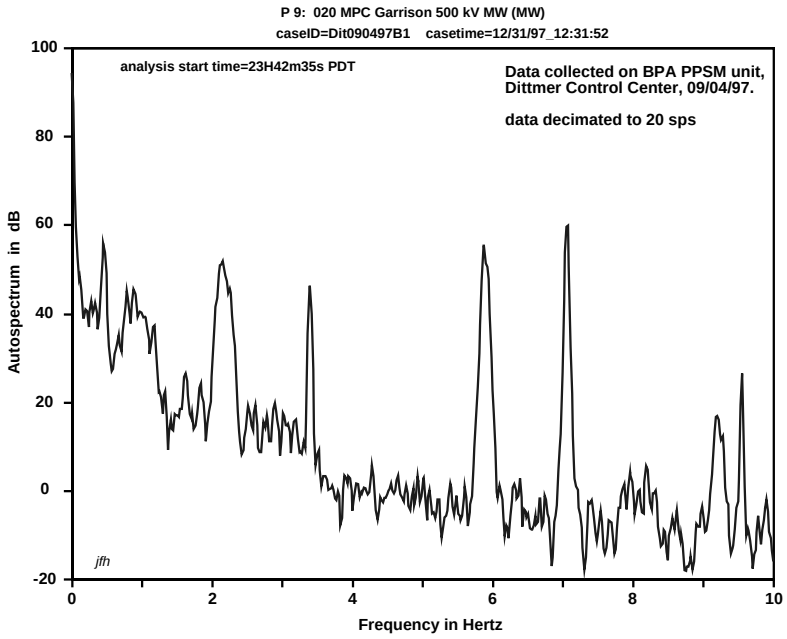

Fig. I-4. Anomalous activity peaks in real power on the MPC–Garrison 500-kV line, as viewed with 20 sps sampling.

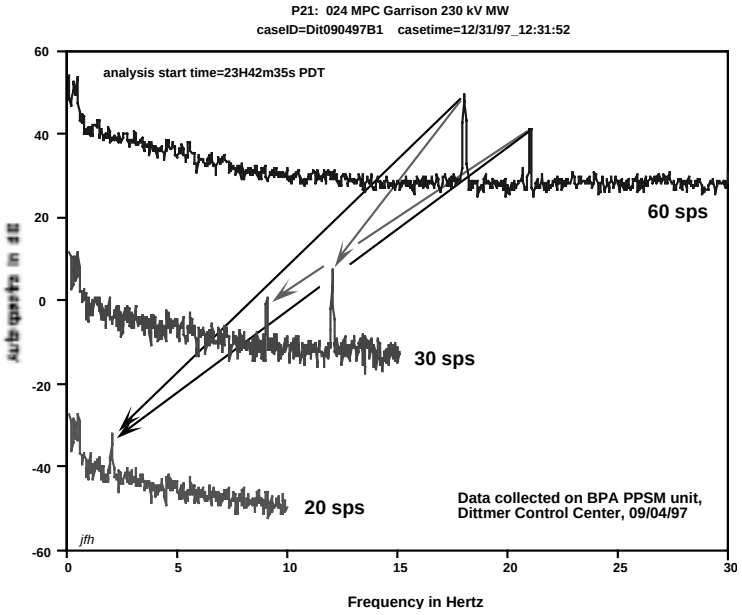

Fig. I-5. Aliasing of activity peaks MPC–Garrison 230-kV line through reductions in sampling rate.

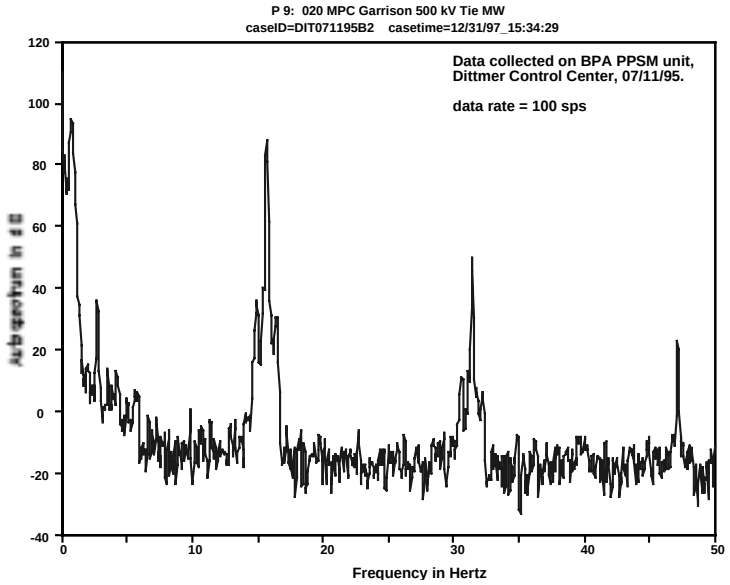

Fig. I-6. Anomalous activity peaks in real power on the MPC–Garrison 500-kV line, as viewed on 07/11/95 with 100 sps sampling.

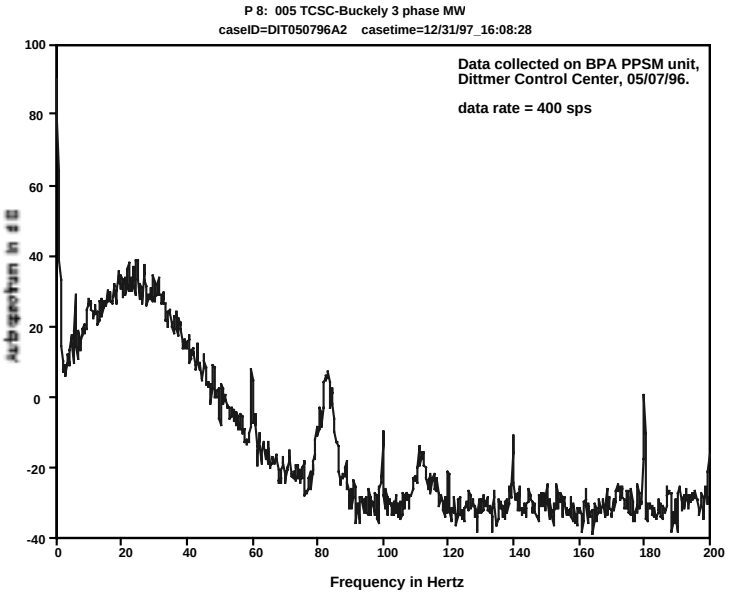

Fig. I-7. Anomalous activity peaks in real power on the TCSC–Buckley 500-kV line, as viewed on 05/07/96 with 400 sps sampling.